

Oxytocin Responses After Dog and Cat Interactions Depend on Pet Ownership and May Affect Interpersonal Trust

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Although many of us interact daily with animals, we have little understanding of how this affects our interactions with people. This study assessed the physiological effects of human-animal interactions and tested if this affected interpersonal trust. Participants (N=141) were assigned to play with a friendly but unfamiliar cat or dog for 10 minutes or to rest quietly in a private room. Blood was obtained from human participants before and after animal interactions or rest, and videos of animal interactions were coded for encounter styles. Participants then made interpersonal monetary decisions to quantify trust and trustworthiness toward strangers. Although oxytocin (OT) fell on average after interactions with both dogs and cats, there was a positive and significant correlation between the change in OT after interacting with a dog and lifetime pet exposure. Participants who had lived with four or more dogs in their lifetimes had a positive increase in OT after interacting with an unknown dog. We found a negative correlation between the change in OT after interacting with a cat and cat ownership. Participants who had a reduction in stress hormones after a dog interaction showed increased trust in strangers. Specifically, a one-percentage-point decrease in the stress hormone adrenocorticotropin hormone increased trust in a stranger by 24 percent. Our findings show that the human OT response to animals depends on previous pet exposure.

Keywords: Hormones, stress, attachment, neuroeconomics, trust

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People live with pets for a variety of reasons and interact with them in different ways, but there is no universal human response to animals. Some people are inseparable from their cats and dogs, while others don't like animals at all. Studies have shown that patients with companion animals have lower blood pressures, heart rates, and stress levels, as well as improved emotional well-being (Jorgenson, 1997; Odendaal, 2000; Barker & Wolen, 2008; Barker et al., 2012). Interacting with a dog for as little as five minutes can lead to a reduction in the stress hormone cortisol, suggesting that animal-assisted therapy may be an effective anti-stress treatment (Odendaal, 2000; Barker & Wolen, 2008).

Chronic stress has been associated with cardiovascular disease, cancer, and depression (Maddock & Pariante, 2001), and the costs of work-related stress are estimated to be as high as four percent of GDP (Hoel et al., 2001). Some organizations have begun permitting employees to bring pets to work as a stress-reduction technique. Indeed, employee perceptions of pets in the office are positive, with the most commonly cited benefit being a perceived lowering of stress (Wells & Perrine, 2001). Barker et al. (2012) found a significant reduction in perceived stress in pet owners who brought their dogs to work compared to those who had pets but did not bring them to work, and compared to

employees who had no pets at all (Barker et al., 2012).

Interactions with animals may affect more than stress. For example, people who have dogs are judged to be more trustworthy than those who do not (Gueguen & Cicotti, 2008). Of particular interest is the finding that human-dog interactions have been associated with increases in oxytocin (OT; Odendaal, 2000; Odendaal & Meintjes, 2003; Nagasawa, et al., 2009), although this effect may be non-robust due to factors like limited sample sizes and poor experimental controls (Beetz et al., 2012; Miller et al., 2009).

Neurochemicals like OT fluctuate to guide human and nonhuman animals' responses to their internal and external environments. Many hormones in human beings, including OT, adrenocorticotropic hormone (ACTH), cortisol (CORT), and testosterone (T), respond to social interactions. As social creatures, humans seek to balance the costs of social interactions (such as fear and danger) with its benefits (such as mating and alliance-building). Changes in neurochemicals affect this calculus, working at different time frequencies that range from milliseconds to hours.

OT is known to be released in women during labor and breastfeeding, and by both sexes during sex. Beyond peri-reproductive behaviors, over a decade of research on the behavioral effects of OT have shown that it increases when one is trusted (Zak, et al., 2004; 2005), touched (Morhenn et al., 2008, 2012), watches an emotional movie (Barraza & Zak, 2009), or engages in a variety of group rituals (Zak, 2012). These studies have been confirmed by intranasal OT infusion studies showing that OT generally increases prosocial or moral behaviors (Zak, 2012; 2011; 2007; 2005; 2004; Kosfeld et al., 2005; Barraza & Zak, 2009; Barraza et al., 2011). OT is a rapid and unconscious signal that

those around us appear to be safe, familiar, or trustworthy.

The effects of OT occur both on the central nervous system (primarily affecting activity in the amygdala, hypothalamus, and anterior cingulate cortex; Bethlehem, et al., 2013; Kirsch et al, 2005), and the peripheral nervous system reducing sympathetic tone via the vagus nerve and inhibition of stress hormones such as ACTH and CORT (Meyer-Lindenberg et al., 2011; Norman et al., 2011). OT is synthesized in the hypothalamus within 1-2 seconds after a stimulus (Zak et al., 2004; 2005) and has a 3-5 minute half-life (Chard et al., 1970). Unlike most neurochemicals, a stimulus causes OT to be released in both the brain and, via the pituitary gland, the blood (Landgraf & Neumann, 2004). This means that a change in OT measured in the blood reflects a change in OT in the brain. Nevertheless, basal (unstimulated) plasma OT and OT in cerebrospinal fluid are unrelated (Dogterom et al., 1977).

Humans are gregariously social, and our neuroanatomy reflects this. Humans appear to have a larger number of frontal cortex OT receptors than other animals (Loup et al., 1991) though definitive cross-species studies have not yet been done. Human behaviors and brain structure suggest that people might use the same attachment system that evolved to care for offspring to attach to animals. The present study seeks to test this hypothesis using a large sample and an accepted methodology to measure the change in OT.

Others have tested this hypothesis but in much narrower ways than we do here. Odendaal (2000) tested N=16 participants and found a significant positive relationship between interacting with one's own dog and changes in plasma OT in both species. A similar study using N=10 females also found an increase in plasma OT in human participants when petting one's own dog (Handlin et al., 2011). Nagasawa et al., (2009) reported that a long gaze (but not a

short gaze) at one's dog increased human urinary OT for N=55. Because of the short half-life of OT and the lack of published kinetics from OT synthesis in the brain to excretion in urine, Nagasawa et al.'s results are in question. Acute changes in OT are best measured through serial blood draws. The cited works also study only pets and their human caretakers. As a result, these studies are conditioned on a potentially long period of attachment between animals and humans than can be difficult to quantify. Conversely, our approach had people interact with unfamiliar but friendly dogs as a stark test of the neurochemical effects of dogs on humans. Our study used different dogs so that the findings were not dependent on interactions with a single animal.

Nothing in the brain happens in isolation. In the present study we also tested whether animal interactions affect the stress hormones ACTH and CORT. Odendaal & Meintjes, (2003) report such a finding for human CORT levels. Service dogs appear to decrease CORT in autistic children (Viau et al., 2010) and health care professionals (Barker et al., 2005). Because our experimental design used a short-duration (10 minute) interaction, we measured CORT along with the faster acting stress hormone ACTH. To rule out spurious findings from noisy physiologic measures, we also included an active behavioral task to assess if neuroendocrine changes in humans affect prosocial behaviors. That is, we tested if the neurophysiologic effect of interacting with an animal would carryover to interpersonal human interactions.

We also included a larger sample size than other studies as well as an active control condition. A total of N=62 participants interacted with unfamiliar dogs and N=47 interacted with unfamiliar cats. Including cats was a natural control since nearly as many households have cats (30.4%) as have dogs (36.5%; American Veterinary Medical

Association, 2012). We also included a second control condition (N=32) of no animal interaction at all. Animal-human interactions were videotaped to test if the quantity and quality of these encounters were associated with physiologic changes.

We hypothesized that interactions with dogs, but not cats or quiet rest, would increase OT, decrease ACTH and CORT, and increase interpersonal trust.

Methods

Timeline

This study adapts the protocol in Zak et al. (2005) to accommodate animals in the experimental design. Six participants were recruited per session and, after baseline blood draws, were randomly assigned to one of three conditions: Dog, Cat, or Rest. In the animal conditions, participants interacted alone with an animal in small, closed rooms for 10 minutes. The Rest condition put participants in the same rooms but had them sit quietly for 10 minutes.

Immediately after the animal interaction or rest, a second blood draw was obtained and participants answered survey questions regarding their moods, pet experience histories, and attitudes. After completion of the surveys, participants were given instruction in the economic decision task and then made monetary transfer choices. After all decisions were made, participants were paid their earnings in private and dismissed. There was no deception of any type in this experiment.

Participants

Participants were recruited from the Claremont Colleges using fliers posted on campus, through social networking sites, and through word of mouth. Recruitment fliers and emails told potential participants that the study would examine the biological bases of decision-making and might involve interactions with dogs or cats. The Institutional Review Boards of Scripps College and Claremont Graduate University approved the study. All participants gave written informed consent prior to inclusion and were assigned an identity-masking code used to ensure anonymity. Experimental sessions were conducted in the early evening at the Center for Neuroeconomics Studies at Claremont Graduate University, and each session lasted approximately 60 minutes. A total of 141 participants were recruited, with 50 percent of them female. The average age of participants was 21.65 (SD = 4.64).

Blood Draws and Assays

Participants were taken to a private room where 28 ml of blood was drawn from an antecubital vein by a qualified phlebotomist. Two 8-ml EDTA whole-blood tubes and one 12-ml serum-separator tube were drawn maintaining a sterile field using Vacutainer® blood collection kits. The initial blood draw established basal OT, CORT, and ACTH.

A second 28-ml blood draw was obtained from each participant immediately following his or her 10-minute interaction with the animal or at the conclusion of the 10-minute rest period. All second blood draws occurred within two minutes after the rest or animal interaction ended. This design takes into account OT's short half-life and seeks to capture participants' physiologic states during the animal interaction.

After phlebotomy, each blood tube was immediately placed on ice before being put

into to a refrigerated centrifuge and spun at 1500 rpm at 4°C for 12 minutes. Plasma and serum were withdrawn and placed into 2-ml polypropylene microtubes with screw caps. The microtubes were immediately placed on dry ice and then transferred to an -80°C freezer until analysis.

Hormones were assayed using either radioimmunoassays (RIA) or enzyme-linked immunosorbent assays (ELISA). Assays were performed at Biomarkers Core at Emory University in Atlanta, Georgia. ACTH and CORT were assayed using an RIA kit from Diagnostic Systems Laboratories (Webster, Texas), while OT was assayed using an ELISA from R&D Systems (Minneapolis, Minnesota). The inter- and intra-assay coefficients of variations were less than 15 percent for all tests. While recent advances in assay design have shown that an RIA with an extraction step measures OT more precisely than an ELISA (McCullough et al., 2013), this study was done in 2010 before the differences between the ELISA and RIA had been established. Since we focus on the change in OT after a stimulus and not OT levels, side-products that the ELISA may measure are likely to disappear when changes in OT are analyzed. As a result, we only report changes in OT.

Economic Decision Task

Participants were instructed in and made a single decision using a variation of the trust game (TG) developed by Berg et al. (1995). Each participant was randomly assigned to a dyad with another participant and then randomly assigned the role of Decision-Maker 1 (DM1) or Decision-Maker 2 (DM2). Both DMs were endowed with \$10 at the start of the task and were extensively instructed about how their decisions would affect their earnings and the earnings of the other dyad member. Interactions between the

participants were conducted exclusively through a computer interface.

The instructions stated that the amount transferred by DM1 would be removed from his or her account and would be tripled and placed in DM2's account. DM2 was then informed by the software of the tripled transfer received from the DM1 in his or her dyad and the total in his or her account. Then, DM2 was prompted by the software to enter an amount, including \$0, that he or she would like to transfer back to the DM1 in the dyad. The amount sent by DM2 to DM1 would be subtracted from DM2's account and would transfer one-for-one into DM1's account. The instructions included several examples of DM1 and DM2 transfers and subsequent earnings. Participants were also prompted to ask questions prior to making decisions.

The transfer from DM1 to DM2 in this task is considered a measure of trust, and the amount returned by DM2 to DM1 is considered a measure of trustworthiness or reciprocity (Smith & Walker, 1993). The classical prediction in economics is that DM2 will return nothing to DM1 regardless of the amount she or he receives. However, in most studies in developed countries, 90-95% of participants show at least some trust and reciprocity (Zak, 2011; Camerer, 2003).

Video

Animal-human interactions were recorded on Sony digital cameras using tripods. Cameras were set up in such a way that both the animal and the human participant were in frame for the majority of the recording. Videos were transferred onto DVDs and given to four independent raters who had an inter-rater reliability of $b = 0.634$, $p < 0.001$. The coding quantified touch, visual gaze, and the use of toys during animal interactions.

Animals

Animals were recruited from lab members based on their friendliness toward strangers. Two animals were used at a time. The most-used dogs were named Rowdy, a Brittany, and Herriot, a beagle, though other dogs of various sizes and breeds were used as well. Cat interactions were conducted using two common housecats. The interaction rooms included toys and treats so that participants had several ways to engage with the animals. Multiple animals were used so that the results did not depend on the behavior of a single dog or cat.

In every experimental session, animals were accompanied by their owners or an animal rights observer. Our focus was on human physiology and behavior after animal interactions, not animal responses. As a result, blood samples were only obtained from people, not animals. Breaks were provided after every experimental session for animals to eat, drink, and use the litter box (cats) or walk in a grassy area (dogs). One dog in the first session appeared to be mildly distressed and was not used in subsequent sessions. All other animals appeared relaxed before, during, and after experimental sessions. Claremont Graduate University's Internal Review Board approved the animal handling protocol; IACUC approval was not necessary as the animals were not being studied.

Surveys

Trusting behaviors can be influenced by a number of underlying psychological factors. In order to untangle these interactions, we administered a number of surveys. These included Satisfaction With Life (SWL; Pavot

OXYTOCIN RESPONSES

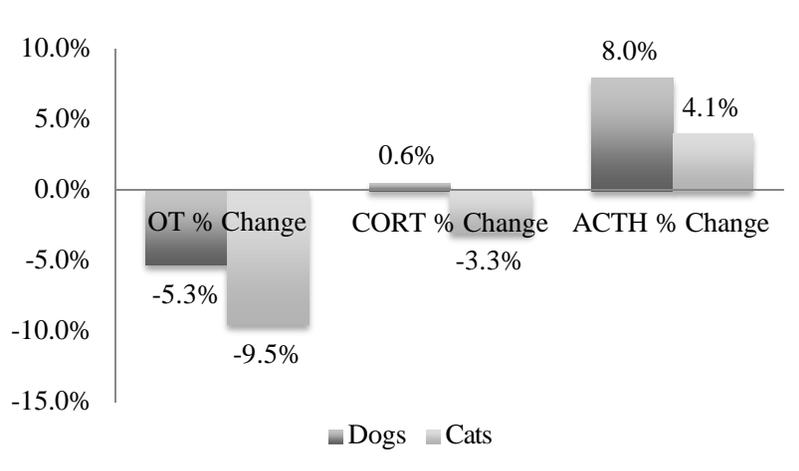


Figure 1: Endocrine changes after animal interactions. Playing with an unfamiliar dog or cat caused a significant reduction in OT and insignificant changes in ACTH and CORT.

& Diener, 1993) that provides a global assessment of one’s flourishing, and the Affect Intensity Measure (AIM; Larsen, 1984) that measures the strength and valence of emotions. We also included a number of questions taken from the General Social Survey regarding attitudes about others (Gleaser et al., 2000) as well as demographic information. Questions regarding one’s feelings about animals and pet ownership history were created for this study and can be found in the Appendix.

Results

Hormones

The physiologic effect of animal encounters was highly variable. The change in OT for those who interacted with dogs varied from a +81% to -40%, while cat interactions produced changed in OT from +72% to -57%. As shown in Figure 1, the average percentage change in OT was negative when participants interacted with both dogs (M=-5.3%, p=0.05) and cats (M=-

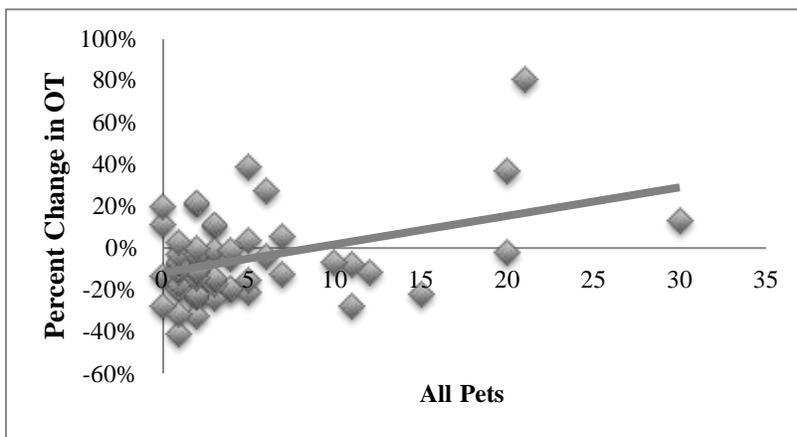


Figure 2a: Percent change in OT and the total number of lifetime pets for people who interacted with a dog. Increases in oxytocin were associated with a higher number of pets owned in a participant’s lifetime.

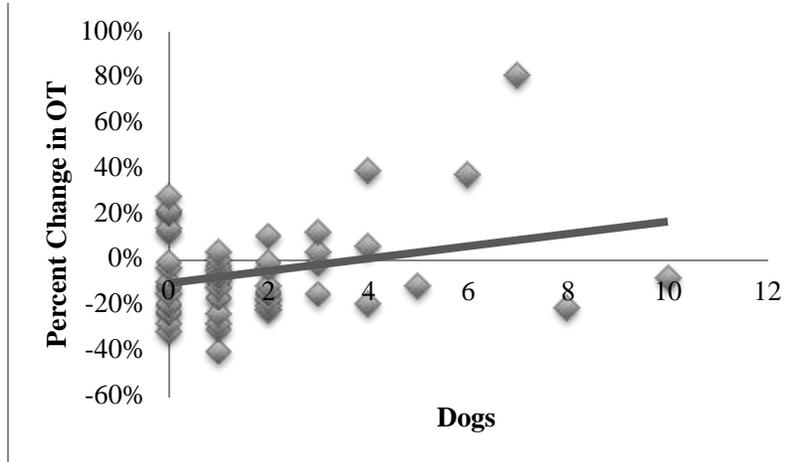


Figure 2b: There was a positive association between the increase in OT and the total number of lifetime dog cohabitations for people who interacted with a dog.

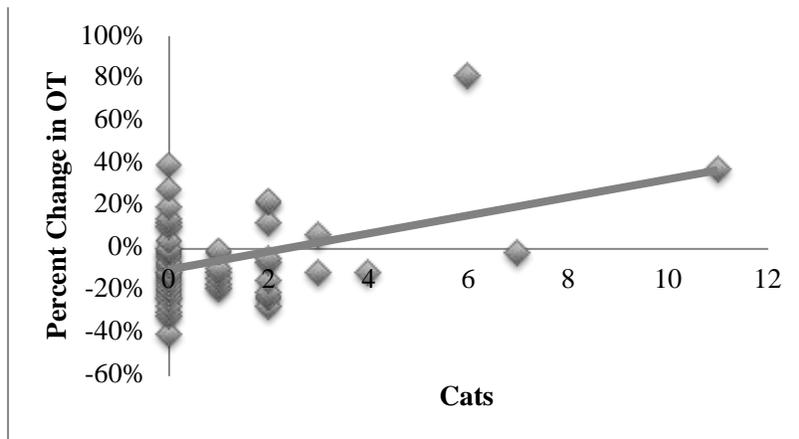


Figure 2c: The number of cats a participant had lived with was positively associated with an increase in OT after interacting with a dog.

9.5%, $p=0.003$). Average percentage changes in stress hormones did not statistically differ from zero after playing with dogs (two-tailed paired t-tests: CORT $M=0.6\%$, $p=0.89$; ACTH $M=8.0\%$, $p=0.18$) or cats (CORT $M=-3.3\%$, $p=0.42$; ACTH $M=4.1\%$, $p=0.45$).

Pet History

We found a positive and significant correlation between the percentage change in OT after interacting with a dog and the number of dogs ($r=0.275$, $p=0.04$), cats ($r=0.410$, $p=0.002$), and total number of pets

one has resided with in one's lifetime ($r=0.403$, $p=0.002$; Figures 2a-c). The significant relationship between the lifetime number of pets owned and the change in OT continues to hold after controlling for age and removing outliers (for instance, one individual reported 30 lifetime pets).

The opposite pattern was found for participants who interacted with cats: There was a negative relationship between the percentage change in OT and the number of cats a participant had lived with in his or her lifetime ($r=-0.334$, $p=0.03$; Figure 3). The relationship between the lifetime number of

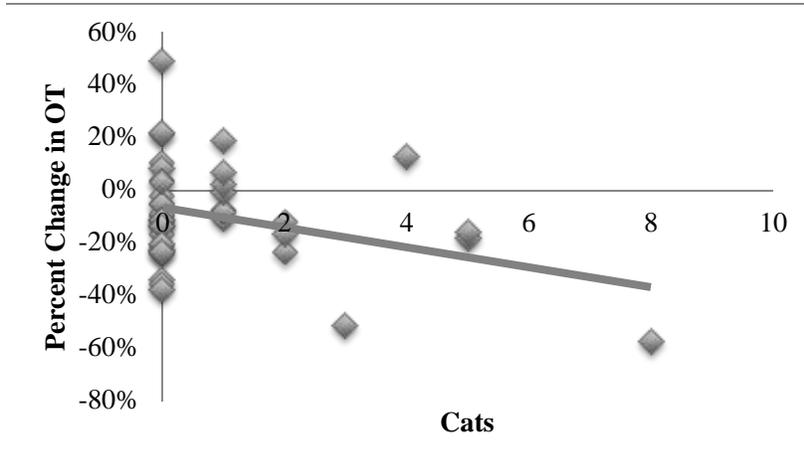


Figure 3: Percent change in OT and the total number of cats one has had for participants who interacted with a cat. A larger number of cats was associated with a greater decrease in OT.

cats owned and the percentage change in OT continued to be significant even after controlling for age ($b = -3.9\%$, $p = 0.02$). The relationship between lifetime number of pets, lifetime number of dogs, and the change in OT after interacting with a cat did not reach statistical significance (Pets owned: $r = -0.21$, $p = 0.19$; Dogs owned: $r = 0.21$, $p = 0.18$).

Interaction Types

While we coded for over two-dozen animal-human interaction variables, only a handful of them were significantly associated with changes in hormones. Table 1 shows the correlation and p -values for all coded variables. Significant correlations were found between petting a dog's belly and an increase in ACTH ($r = 0.34$, $p = 0.01$); the dog lying down away from the person and an increase in OT ($r = 0.26$, $p = 0.05$); and eye contact between the participant and the dog and an increase in OT ($r = 0.29$, $p = 0.02$). The correlation between the number of times a participant made eye contact with a dog and changes in OT replicates earlier work (Nagasawa et al., 2009). For participants who interacted with a cat, offering the cat a toy was associated with an increase in OT ($r = 0.30$, $p = 0.05$).

Trusting Behaviors

Overall, there were no significant differences among the three different treatment groups and the amount transferred by DM1s in the trust game (Dog: \$6.97; Cat: \$6.71; Control: \$6.28; $F = 0.14$, $p = 0.86$). Return transfers by DM2s also were statistically the same across groups (Dogs: 50.5%; Cats: 41.4%; Control: 57%; $F = 1.77$, $p = 0.18$).

When we looked at the relationship between stress hormones and trusting behaviors, we found that for DM1s who interacted with dogs, a reduction in ACTH marginally increased trust in a stranger ($r = -0.349$, $p = 0.06$; Figure 4). For those in the dog group, the changes in OT and CORT were unrelated to trust ($p > 0.05$). The negative relationship between the change in ACTH and trust for those who interacted with dogs persists after controlling for changes in OT, age, and gender ($b = -2.77$, $p = 0.02$, $R^2 = 0.32$).

OXYTOCIN RESPONSES

Dog Interaction Correlations					Cat Interaction Correlations				
% Change in		OT	CORT	ACTH	% Change in		OT	CORT	ACTH
Petting - Total # of times	<i>r</i> <i>p</i>	0.09 0.49	0.04 0.75	0.22 0.10	Petting - Total # of times	<i>r</i> <i>p</i>	-0.05 0.74	-0.01 0.96	0.09 0.60
Petting - Head and face	<i>r</i> <i>p</i>	0.09 0.49	0.15 0.27	0.07 0.60	Petting - Head and face	<i>r</i> <i>p</i>	0.02 0.90	-0.01 0.94	0.03 0.87
Petting - Side and back	<i>r</i> <i>p</i>	0.06 0.66	-0.03 0.84	0.17 0.21	Petting - Side and back	<i>r</i> <i>p</i>	-0.03 0.84	-0.01 0.96	0.16 0.32
Petting - Belly	<i>r</i> <i>p</i>	0.06 0.64	-0.08 0.58	0.34 0.01	Petting - Belly	<i>r</i> <i>p</i>	-0.25 0.12	0.03 0.83	-0.01 0.95
Toys (offers)	<i>r</i> <i>p</i>	-0.12 0.38	0.12 0.39	0.12 0.40	Toys (offers)	<i>r</i> <i>p</i>	0.30 0.05	0.17 0.28	0.04 0.80
Treats (offers)	<i>r</i> <i>p</i>	-0.10 0.47	-0.24 0.07	-0.13 0.34	Treats (offers)	<i>r</i> <i>p</i>	-0.02 0.89	-0.25 0.12	0.02 0.89
Lying down (to engage person)	<i>r</i> <i>p</i>	0.00 0.99	0.15 0.25	0.16 0.25	Lying down (to engage person)	<i>r</i> <i>p</i>	-0.19 0.24	0.03 0.87	0.08 0.62
Lying down away from person	<i>r</i> <i>p</i>	0.26 0.05	0.06 0.68	0.05 0.71	Lying down away from person	<i>r</i> <i>p</i>	0.01 0.94	-0.03 0.83	0.14 0.38
Whining # of times	<i>r</i> <i>p</i>	-0.05 0.71	0.11 0.44	0.19 0.16	Whining # of times	<i>r</i> <i>p</i>	0.26 0.09	0.06 0.70	-0.04 0.82
Facing door or window	<i>r</i> <i>p</i>	0.18 0.18	0.15 0.27	-0.15 0.28	Facing door or window	<i>r</i> <i>p</i>	0.14 0.38	-0.18 0.26	-0.26 0.10
Person says name	<i>r</i> <i>p</i>	-0.07 0.60	-0.01 0.96	0.03 0.85	Person says name	<i>r</i> <i>p</i>	0.00 1.00	-0.19 0.25	0.09 0.58
Response to name	<i>r</i> <i>p</i>	-0.12 0.39	-0.03 0.83	-0.20 0.14	Response to name	<i>r</i> <i>p</i>	0.09 0.56	-0.01 0.96	0.00 0.99
Response to non- name verbal	<i>r</i> <i>p</i>	0.04 0.77	-0.16 0.24	-0.16 0.24	Response to non- name verbal	<i>r</i> <i>p</i>	0.09 0.59	-0.23 0.15	0.05 0.76
Response to gesture	<i>r</i> <i>p</i>	0.02 0.86	-0.15 0.28	0.05 0.73	Response to gesture	<i>r</i> <i>p</i>	0.01 0.95	-0.15 0.35	0.08 0.61
Person changes position	<i>r</i> <i>p</i>	- 0.66	0.01 0.96	-0.14 0.32	Person changes position	<i>r</i> <i>p</i>	-0.22 0.17	0.05 0.78	0.08 0.64
Animal initiates contact	<i>r</i> <i>p</i>	0.03 0.81	0.08 0.57	0.05 0.70	Animal initiates contact	<i>r</i> <i>p</i>	0.05 0.77	-0.18 0.27	0.21 0.20
Eye Contact	<i>r</i> <i>p</i>	0.29 0.02	0.21 0.12	0.21 0.12	Eye Contact	<i>r</i> <i>p</i>	0.12 0.44	0.04 0.81	-0.15 0.35

Table 1: Endocrine changes associates with human-animal interactions. All p values are two-tailed tests. For dogs, Eye contact, petting, offering treats, and the number of times the dog lied down away from the participant were significantly correlated with hormone changes. For cat interactions, offering a toy during the session was positively correlated with changes in OT.

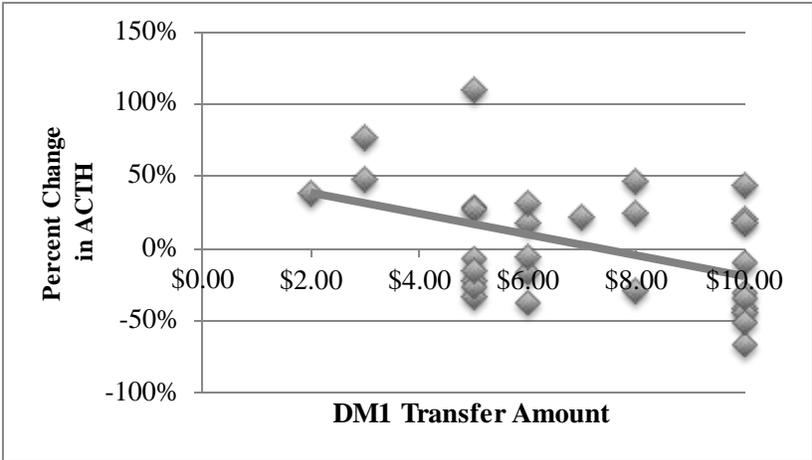


Figure 4: Percent change in ACTH and DM1 transfer amount after dog interactions. For participants who interacted with a dog, larger reductions in ACTH were associated with higher DM1 transfer amounts.

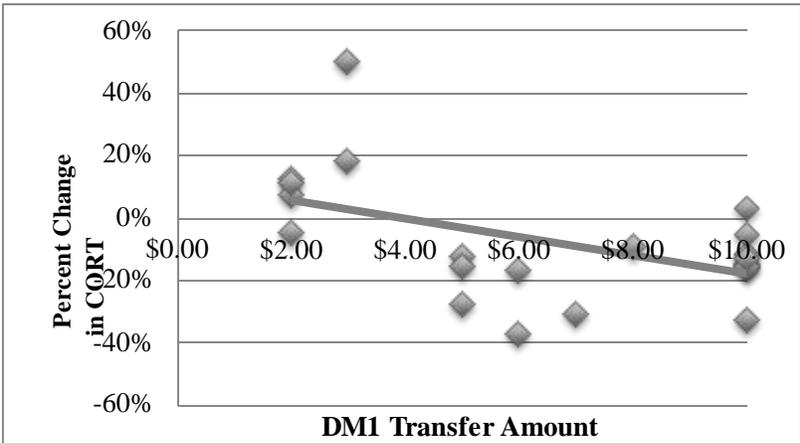


Figure 5: Percent change in CORT and DM1 transfer amount after cat interactions. For those participants who interacted with a cat, larger reductions in CORT were associated with higher DM1 transfer amounts.

For those who interacted with cats, a reduction in CORT increased trust ($r=-0.495$, $p=0.02$; Figure 5). Neither the change in OT nor the change in ACTH were associated with trusting behaviors for those who interacted with cats ($ps>.05$). The negative relationship between changes in CORT and trust for participants who interacted with cats is also robust after controlling for the same variables as in the dog analysis ($b=-7.10$, $p=0.06$, $R^2=0.30$).

These findings caused us to further examine the relationship between stress

hormones and trust. We found that 65% of DMIs had negative CORT changes after interacting with either animal, with an average percentage change of -17%. The increase in CORT for the other 35% only averaged 1.7%. Participants with a decrease in CORT did not exhibit a difference in trust from those whose CORT increased (Increase: \$7.25; Decrease: \$6.94; $p=0.11$). Similarly, 51% of DMIs had negative ACTH changes from animal interactions that averaged -28%, while the 49% of those with an increase in ACTH averaged just 2%. There was no

difference in trust between groups (Increase: \$7.15; Decrease: \$6.48; $p=0.40$). These inconclusive results could be the result of measurement error from the assay. Indeed, we found a lack of the expected correlation between ACTH and CORT in participants who interacted with animals in our sample ($r = -.15$, $p = .12$). In order to derive robust results, we assessed trust in the 32% of participants who had reductions in both ACTH and CORT after animal interactions. We found that participants with reductions in both stress hormones demonstrated 25% higher trust compared to those who did not have an unambiguous reduction in stress (\$8.11 vs. \$6.48; $p=0.02$).

For DM2s who interacted with either type of animal, there were no significant correlations between hormone changes and trustworthiness. (Cats: CORT $r = -0.13$, $p = 0.57$; OT $r = -0.08$, $p = 0.72$; ACTH $r = 0.07$, $p = 0.76$; Dogs: CORT $r = 0.02$, $p = 0.91$; OT $r = 0.03$, $p = 0.87$; ACTH $r = 0.13$, $p = 0.51$). This was expected since the signal of trust DM2s receive from DM1s is likely to overwhelm the effects of dog or cat interactions (Zak et al., 2005; 2011). There was also no significant difference in DM2 trustworthiness for those with negative changes in CORT (Negative: 51%; Positive: 40%; $p = 0.11$), ACTH (Negative: 46%; Positive: 46%, $p = 0.98$), or both ACTH and CORT (Negative: 50%; Positive: 45%; $p = 0.59$).

As in previous research (Zak et al., 2005), the trait and attitude surveys showed little association with trusting behaviors. Only those who thought money was very important showed less trust in strangers ($r = -0.40$, $p = 0.01$). On the other hand, trustworthiness was positively correlated with emotional lability as measured by the AIM ($r = 0.51$, $p = 0.001$) and negatively associated with a desire to make money any way possible ($r = -0.46$, $p = 0.00$) and a stated distrust of strangers ($r = -0.29$, $p = 0.06$).

Discussion

This study sought to characterize the physiologic effects of human-animal interactions and to test if physiologic changes due to animals affected human-human interactions. As expected, our findings were more nuanced than were our hypotheses. Rather than interactions with dogs uniformly increasing OT, we found that only a subset of participants (27%) responded this way. If one owned a sufficient number of dogs, cats, or pets in one's lifetime, this increased the likelihood that interacting with an unfamiliar dog increased OT. For our data, if an average participant had resided with four or more dogs in his or her lifetime, then interacting with a dog in the lab produced an OT increase. This suggests that pet experience may prime the brain for physiologic attachment (an increase in OT) when one interacts with an unknown dog. There is evidence in rodents that rich social environments stimulate oxytocin receptor binding and result in increased social behaviors (Champagne & Meaney, 2007). It is possible that having pets in one's household has a similar effect on human beings.

We also tested the effect of human-animal interactions on interpersonal behaviors by asking participants to make a single monetary decision in which they could exhibit trust or trustworthiness through a computer-aided monetary transfer to a stranger. We found that a reduction in stress after playing with a dog linearly increased trust in a stranger. In our sample, a one percentage point decrease in ACTH increased trust by 24%, a substantial size effect. A further analysis revealed that a robust measure of stress reduction (a decline in both CORT and ACTH) from interacting with either a dog or cat was associated with 25% greater trust in a stranger. Playing with an animal reduced stress in approximately

one-third of participants. Compared to those who did not get a stress reduction, this group of participants were more likely to self-identify as “dog people” ($r=0.19$, $p=0.05$) and report higher levels of religiosity in a several questions ($p<.05$). Future studies should seek to understand the circumstances in which interacting with an unknown pet reliably reduces stress.

We did find several lines of evidence regarding the type of interactions with animals that affected OT. Eye contact with a dog was found to correlate with an increase in OT, confirming earlier work (Nagasawa, et al., 2009). Given that both humans and dogs are social animals, intermittent eye contact can be interpreted as a display of trust and an engagement in a bonding activity. The dog lying down away from the participant also positively correlated with changes in OT. This behavior could indicate a degree of comfort the dog has toward the person in the room, enabling the human to feel more attached to the animal. In interactions between participants and cats, we found positive correlations between changes in OT and how many times a participant offered a toy to the animal. The lack of an increase in OT with other play styles may be due to the limited motivation by cats to socialize based on their generally solitary nature. By offering the cat a toy, a participant appears to be forming a connection with the animal, resulting in an increase in OT. The conditional nature of our findings is consistent with reports showing that OT infusion on human social interactions is conditional on set and setting (de Dreu et al., 2010).

For the scientific community, our discovery that an increase in OT after interacting with a dog was conditional on previous pet experience may help explain the inability of other labs to replicate Odendaal’s (2000) findings of an increase in OT after interacting with one’s own dog. The present

study had a large number of participants interacting with unfamiliar dogs, setting the bar higher to find an OT effect from cross-species interactions. It is also interesting that previous cat ownership had a linearly decreasing effect on OT after interacting with a cat. This could be due the reduced quantity and quality of participant interactions in cats versus dogs. We hope that this research stimulates other studies on cross-species attachment, a phenomenon that may be more common than once thought (Zak, 2014).

Our findings may also prove useful to professionals using animal-assisted therapy. Encouraging patients to engage in eye contact, petting, and other bonding behaviors with service animals may be the most effective way to reduce stress and increase oxytocin. Our analysis also suggests that animal therapy may have a cumulative effect as we found for pet ownership on oxytocin release. Programs that provide live-in therapy dogs to warfighters who need emotional support, for example, due to post-traumatic stress disorder, may have a stronger therapeutic effect than short-duration visits with dogs (Altschuler, 1999). Patients who have a history of pet ownership may also achieve the benefits of animal-assisted therapy more rapidly than those who have not resided with pets. Our findings also support this use of animal therapy for other anxiety-related maladies such as autism spectrum disorder (ASD). Children with ASD have a diminished stress response when they hold guinea pigs (Kršková, Talarovičová, & Olexová, 2010; O’Haire, McKenzie, Beck, & Slaughter, 2015). Dog therapy for those with ASD may have even stronger effects (Solomon, 2010).

Dogs appear to have a special relationship with humans. This is reflected in the intense physiologic response to dogs for those who have a history of pet exposure. Our research elucidates the mechanism that is at least partially responsible for the positive

effects of animal-assisted therapy and bring-your-dog-to-work programs. The benefits of dogs in our lives appear to grow the more we are exposed to them.

References

- Altschuler, E. (1999). Pet-facilitated therapy for posttraumatic stress disorder. *Annals of Clinical Psychiatry, 11*(1), 29-30.
- American Veterinary Medical Association. (2012). U.S. Pet Ownership & Demographics Sourcebook. Retrieved from <https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-pet-ownership.aspx>.
- Barraza, J., McCullough, M., Ahmadi, S., & Zak, P. (2011). Oxytocin infusion increases charitable donations regardless of monetary resources. *Hormones and Behavior, 60*(2), 148-151.
- Barraza, J., & Zak, P. (2009). Empathy toward strangers triggers oxytocin release and subsequent generosity. *Annals of the New York Academy of Sciences, 1167*(1), 182-189.
- Barker, R., Knisely, J., Barker, S., Cobb, R., & Schubert, C. (2012). Preliminary investigation of employee's dog presence on stress and organizational perceptions. *International Journal of Workplace Health Management, 5*(1), 15-30.
- Barker S., Knisely J., McCain N., & Best A. (2005). Measuring stress and immune responses in health care professionals following interaction with a therapy dog: a pilot study. *Psychol. Rep. 96*, 713-729. doi:10.2466/pr0.96.3.713-729
- Barker, S., & Wolen, A. (2008). The benefits of human-companion animal interaction: A review. *Journal of veterinary medical education, 35*(4), 487-495.
- Betz, A., Uvnäs-Moberg, K., Julius, H., & Kotrschal, K. (2012). Psychosocial and psychophysiological effects of human-animal interactions: the possible role of oxytocin. *Frontiers in Psychology, 3*, 234.
- Berg, J., Dickhaut, J., & McCabe, K. (1995). Trust, reciprocity, and social history. *Games and economic behavior, 10*(1), 122-142.
- Bethlehem, R., van Honk, J., Auyeung, B., & Baron-Cohen, S. (2013). Oxytocin, brain physiology, and functional connectivity: a review of intranasal oxytocin fMRI studies. *Psychoneuroendocrinology, 38*(7), 962-974.
- Camerer, C. (2003). *Behavioral game theory: Experiments in strategic interaction*. Princeton University Press.
- Champagne, F., & Meaney, M. (2007). Transgenerational effects of social environment on variations in maternal care and behavioral response to novelty. *Behavioral neuroscience, 121*(6), 1353-1363.
- Chard, T., Boyd, N., Forsling, M., McNeilly, A., & Landon, J. (1970). The development of a radioimmunoassay for oxytocin: the extraction of oxytocin from plasma, and its measurement during parturition in human and goat blood. *Journal of Endocrinology, 48*(2), 223-234.
- De Dreu, C., Greer, L., Handgraaf, M., Shalvi, S., Van Kleef, G., Baas, M., ...
- Feith, S. (2010). The neuropeptide oxytocin regulates parochial altruism in intergroup conflict among humans. *Science, 328*(5984), 1408-1411.
- Dogterom, J., van Wimersma Greidanus, T., & Swaab, D. (1977). Evidence for the release of vasopressin and oxytocin into cerebrospinal fluid: measurements in plasma and CSF of intact and hypophysectomized rats. *Neuroendocrinology, 24*(2), 108-118.
- Hoel, H., Sparks, K., & Cooper, C. (2001). The cost of violence/stress at work and the benefits of a violence/stress-free

- working environment. Geneva: *International Labour Organization*.
- Guéguen, N., & Ciccotti, S. (2008). Domestic dogs as facilitators in social interaction: An evaluation of helping and courtship behaviors. *Anthrozoos: A Multidisciplinary Journal of The Interactions of People & Animals*, 21(4), 339-349.
- Glaeser, E., Laibson, D., Scheinkman, J., & Soutter, C. (2000). Measuring trust. *Quarterly Journal of Economics*, 115(3): 811-846.
- Handlin, L., Hydbring-Sandberg, E., Nilsson, A., Ejdebäck, M., Jansson, A., & Uvnäs-Moberg, K. (2011). Short-term interaction between dogs and their owners: effects on oxytocin, cortisol, insulin and heart rate—an exploratory study. *Anthrozoös*, 24(3), 301-315.
- Jorgenson, J. (1997). Therapeutic use of companion animals in health care. *Image: the Journal of Nursing Scholarship*, 29(3), 249-254.
- Kirsch, P., Esslinger, C., Chen, Q., Mier, D., et al. (2005). Oxytocin modulates neural circuitry for social cognition and fear in humans. *Journal of Neuroscience*, 25(49), 11489-11493.
- Kosfeld, M., Heinrichs, M., Zak, P., Fischbacher, U., & Fehr, E. (2005). Oxytocin increases trust in humans. *Nature*, 435(7042), 673-676.
- Kršková, L., Talarovičová, A., & Olexová, L. (2010). Guinea pigs—The “Small Great” Therapist for Autistic Children, or: Do Guinea Pigs Have Positive Effects on Autistic Child Social Behavior? *Society & Animals*, 18(2), 139-151.
- Landgraf, R., & Neumann, I. (2004). Vasopressin and oxytocin release within the brain: a dynamic concept of multiple and variable modes of neuropeptide communication. *Frontiers in neuroendocrinology*, 25(3), 150-176.
- Larsen, R., & Diener, E. (1987). Affect intensity as an individual difference characteristic: A review. *Journal of research in personality*, 21(1), 1-39.
- Loup, F., Tribollet, E., Dubois-Dauphin, M., & Dreifuss, J. (1991). Localization of high-affinity binding sites for oxytocin and vasopressin in the human brain. An autoradiographic study. *Brain research*, 555(2), 220-232.
- Maddock, C., & Pariante, C. (2001). How does stress affect you? An overview of stress, immunity, depression and disease. *Epidemiologia e psichiatria sociale*, 10(03), 153-162.
- McCullough, M., Churchland, P., & Mendez, A. (2013). Problems with measuring peripheral oxytocin: can the data on oxytocin and human behavior be trusted?. *Neuroscience & Biobehavioral Reviews*, 37(8), 1485-1492.
- Meyer-Lindenberg, A., Domes, G., Kirsch, P., & Heinrichs, M. (2011). Oxytocin and vasopressin in the human brain: social neuropeptides for translational medicine. *Nature Reviews Neuroscience*, 12(9), 524-538.
- Miller, S., Kennedy, C., DeVoe, D., Hickey, M., Nelson, T., & Kogan, L. (2009). An examination of changes in oxytocin levels in men and women before and after interaction with a bonded dog. *Anthrozoos: A Multidisciplinary Journal of The Interactions of People & Animals*, 22(1), 31-42.
- Morhenn, V., Park, J., Piper, E., & Zak, P. J. (2008). Monetary sacrifice among strangers is mediated by endogenous oxytocin release after physical contact. *Evolution and Human Behavior*, 29, 375–383.
- Morhenn, V., Beavin, L., & Zak, P. (2012). Massage increases oxytocin and reduces adrenocorticotropin hormone in humans. *Alternative Therapies in Health and Medicine*, 18(6), 11-18

- Nagasawa, M., Kikusui, T., Onaka, T., & Ohta, M. (2009). Dog's gaze at its owner increases owner's urinary oxytocin during social interaction. *Hormones and Behavior*, 55(3), 434-441.
- Norman, G., Cacioppo, J., Morris, J., Malarkey, W., Berntson, G., & DeVries, A. (2011). Oxytocin increases autonomic cardiac control: moderation by loneliness. *Biological psychology*, 86(3), 174-180.
- Odendaal, J., & Meintjes, R. (2003). Neurophysiological correlates of affiliative behaviour between humans and dogs. *The Veterinary Journal*, 165(3), 296-301.
- Odendaal, J. (2000). Animal-assisted therapy—magic or medicine?. *Journal of psychosomatic research*, 49(4), 275-280.
- Odendaal, J., & Meintjes, R. (2003). Neurophysiological correlates of affiliative behaviour between humans and dogs. *The Veterinary Journal*, 165(3), 296-301.
- O'Haire, M., McKenzie, S., Beck, A., & Slaughter, V. (2015). Animals may act as social buffers: Skin conductance arousal in children with autism spectrum disorder in a social context. *Developmental psychobiology*, 57(5), 584-595.
- Pavot, W., & Diener, E. (1993). Review of the satisfaction with life scale. *Psychological assessment*, 5(2), 164.
- Smith, V., & Walker, J. (1993). Rewards, experience and decision costs in first price auctions. *Economic Inquiry*, 31(2), 237-244.
- Solomon, O. (2010). What a dog can do: Children with autism and therapy dogs in social interaction. *Ethos*, 38(1), 143-166.
- Viau, R., Arsenault-Lapierre, G., Fecteau, S., Champagne, N., Walker, C., & Lupien, S. (2010). Effect of service dogs on salivary cortisol secretion in autistic children. *Psychoneuroendocrinology*, 35(8), 1187-1193.
- Wells, M., & Perrine, R. (2001). Critters in the cube farm: perceived psychological and organizational effects of pets in the workplace. *Journal of occupational health psychology*, 6(1), 81.
- Zak, P. (2014). Dogs (and Cats) Can Love. The Atlantic, April 22, Retrieved from <http://www.theatlantic.com/health/archive/2014/04/does-your-dog-or-cat-actually-love-you/360784/>
- Zak, P., Kurzban, R., & Matzner, W. (2004). The neurobiology of trust. *Annals of the New York Academy of Sciences*, 1032(1), 224-227.
- Zak, P., Kurzban, R., & Matzner, W. (2005). Oxytocin is associated with human trustworthiness. *Hormones and Behavior*, 48(5), 522-527.
- Zak, P., Stanton, A., & Ahmadi, S. (2007). Oxytocin increases generosity in humans. *PLoS One*, 2(11), e1128.
- Zak, P. (2011). The physiology of moral sentiments. *Journal of Economic Behavior & Organization*, 77: 53-65.
- Zak, P. (2012). *The Moral Molecule: The Source of Love and Prosperity*. New York: Dutton.

Appendix: Survey on Disposition Towards Animals

Have you even been threatened or physically assaulted by a dog? (y/n)

Have you ever been attacked by a cat? (y/n)

Have you ever interacted with a farmed animal (pig, chicken, goat, sheep, etc.)? (y/n)
If yes, on how many occasions?

Have you ever been to a zoo? (y/n)
If yes, on approximately how many occasions?

Have you ever observed animals in the wild? (y/n)
If yes, on approximately how many occasions?

Have you ever been to a circus? (y/n)
If yes, on approximately how many occasions?

Please indicate whether you agree with the following statements (1-5)

On the whole, I consider myself to be a “dog person.”

On the whole, I consider myself to be a “cat person.”

I would choose the company of animals over most people.

I have positive memories of dogs in my life.

I have positive memories of cats in my life.

I feel that dogs have unique personalities.

I feel like cats have unique personalities.

I feel that humans can treat animals anyway we want.

I think there is a connection between human violence towards animals and human violence towards other humans.

I think compassion towards animals can strengthen society.

I believe animals should receive moral consideration.

I feel that we should not inflict unnecessary suffering on animals.

I feel that animals should have legal protection.

In general, I feel that our society treats animals well.

I consider the treatment of animals when purchasing food.

I consider the treatment of animals when purchasing cleaning/beauty products.

I find it easier to interact with dogs than cats.

I find it easier to interact with cats than dogs.

I find it easier to interact with humans than animals.

I feel that dogs show emotional complexity.

I feel that cats display individual preferences.

I feel that cats can express their own likes and dislikes.